Claims

1. A titanium oxide-based photocatalyst which is characterized by containing an additional metal compound in titanium oxide and developing a photocatalytic activity by irradiation with visible light.

2. A titanium oxide-based photocatalyst as set forth in claim 1 wherein the additional metal compound is at least one compound selected from a metal halide, a metal complex, a metal hydroxide, and a metal oxide.

3. A titanium oxide-based photocatalyst as set forth in claim 2 wherein the metal complex is one or both of a heteropoly acid and an isopoly acid.

4. A titanium oxide-based photocatalyst as set forth in claim 1 or 2 wherein the content of the additional metal compound as a metal is at least 0.1 mass % and at most 300 mass % based on the titanium oxide.

5. A titanium oxide-based photocatalyst which is characterized by containing a metal halide in titanium oxide and having a thermal desorption spectrum in which a peak of a molecular ion or a fragment ion of a halogen-containing substance appears at a temperature of 623 K or higher.

6. A titanium oxide-based photocatalyst as set forth in claim 1 or 5 wherein the metal is at least one selected from Ti, Si, V, Sn, Sb, Si, W, Nb, Bi, P, Mo, Cs, Ge, As, and Ce.

7. A titanium oxide-based photocatalyst as set forth in claim 2 or 5 wherein the halide is a chloride.

8. A titanium oxide-based photocatalyst developing a photocatalytic activity by irradiation with visible light, which is characterized by having an ESR spectrum measured at a temperature of at least 5 K in which a peak is observed in the range in which the g value is 1.950 - 2.030 when irradiated with visible light, that peak not being substantially observed in the dark.

9. A titanium oxide-based photocatalyst developing a photocatalytic activity by irradiation with visible light, which is characterized by having an ESR spectrum measured at room temperature in a substantially oxygen-free atmosphere in which the highest peak observed in the range in which the g value is 1.950 - 2.030 when irradiated with visible light has a peak intensity with a half life of at least 3 minutes after the irradiation with visible light is stopped.

10. A titanium oxide-based photocatalyst as set forth in claim 8 or 9 which has an ESR spectrum measured at a temperature lower than 77K in which a peak appears in the range in which the g value is 1.986 - 1.994.

11. A titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, and 9 wherein the titanium oxide has absorptivity for visible light.

12. A titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, and 9 wherein the titanium oxide has oxygen defects.

13. A titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, and 9 wherein the primary crystal structure of the titanium oxide is anatase.

14. A method for the preparation of a titanium oxide-based photocatalyst characterized in that titanium oxide and/or its precursor is brought into contact with a reactive medium containing a metal halide of the formula MX_n or MOX_n (wherein M = a metal, X = a halogen, and n = an integer).

15. A method for the preparation of a titanium oxide-based photocatalyst as set forth in claim 14 which further includes subjecting the titanium oxide and/or its precursor to contact with water and/or heat treatment after the contact with the reactive medium.

16. A method for the preparation of a titanium oxide-based photocatalyst as set forth in claim 14 which further includes performing contact with a heteropoly acid and/or an isopoly acid after the contact with the reactive gas, or after subsequent contact with water and/or heat treatment.

17. A titanium oxide-based photocatalyst prepared by a method as set forth in any of claims 14 to 16.

18. A photocatalytic functional product characterized by comprising a substrate having a titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, 9, and 17 deposited on a surface of the substrate.

19. A photocatalytic functional product characterized by comprising a substrate having a film which comprises a titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, 9, and 17 and a binder component formed on a surface of the substrate, the content of the photocatalyst in the film being 5 - 95 mass %.

20. A photocatalyst dispersion characterized by comprising a titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, 9, and 17 dispersed in a solvent.

21. A photocatalyst dispersion as set forth in claim 20 wherein the photocatalyst has an average particle diameter of at most 500 nm.

22. A photocatalytic coating fluid characterized by comprising a titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, 9, and 17 in a solvent.

23. A photocatalytic coating fluid characterized by comprising a titanium oxide-based photocatalyst as set forth in any of claims 1, 2, 8, 9, and 17 and a binder in a solvent, the content of the titanium oxide-based photocatalyst being in the range of 5 - 95 mass % based on the total nonvolatile content in the fluid.

24. A photocatalytic coating fluid characterized in that it is prepared using a photocatalyst dispersion as set forth in claim 21.

25. A method for the manufacture of a photocatalytic functional product characterized by applying a coating fluid as set forth in claim 22, 23, or 24 to a surface of a substrate.

26. A method for the preparation of a photocatalytic coating fluid characterized by mixing a binder with a photocatalyst dispersion as set forth in claim 21.

27. A method for the manufacture of a photocatalytic functional product characterized by depositing titanium oxide and/or its precursor on a surface of a substrate followed by bringing the surface into contact with a reactive medium containing a metal halide of the formula MX_n or MOX_n (wherein M = a metal, X = a halogen, and n = an integer).

28. A method as set forth in claim 27 which further includes subjecting the surface of the substrate to contact with water and/or heat treatment after the contact with the reactive medium.

29. A method as set forth in claim 27 which further includes bringing the surface of the substrate into contact with a heteropoly acid and/or an isopoly acid after the contact with the reactive gas, or after subsequent contact with water and/or heat treatment.

30. A method as set forth in claim 15 or 28 wherein the heat treatment is carried out in a temperature range of 373 - 873 K.

31. A method as set forth in claim 14 or 27 wherein the metal halide is at least one compound selected from $TiCl_4$, $VOCl_3$, $SnCl_4$, $SbCl_5$, $SiCl_4$, WCl_6, and $BiCl_3$.

32. A method as set forth in claim 31 wherein the metal halide is $TiCl_4$.

33. A method as set forth in claim 14 or 27 which further includes subjecting the titanium oxide and/or its precursor or the substrate to heat treatment in a temperature range of 323 - 823 K or to wet processing prior to the contact with the reactive gas.

34. A method as set forth in claim 14 or 27 wherein the contact with the

reactive gas is performed in a temperature range of 323 - 873 K.

35. A method as set forth in claim 14 or 27 wherein the reactive medium is gaseous and its base gas is a nonoxidizing gas.

36. A method as set forth in claim 35 wherein the base gas comprises hydrogen and/or nitrogen.

37. A method as set forth in claim 14 or 27 wherein the titanium oxide and/or its precursor is prepared via a step of neutralizing at least one compound selected from titanium tetrachloride, titanium sulfate, and titanyl sulfate with a nitrogen-containing base.